

A MODEL OF SEASONAL VARIABILITY IN THE INDONESIAN ARCHIPELAGO

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LONG-TERM GOALS

The ultimate goal is to determine which of the straits and seas within the Indonesian archipelago needs to be included explicitly in the multi-level, finite-difference, ocean general circulation models (GCMs) used in forecasting, and which can be grouped together, so making them easily represented by finite-difference grids of cost-effective resolution. Making the determination requires a detailed understanding of observations and development of new theories and process models.

SCIENTIFIC OBJECTIVES

To construct a semi-analytical process model of seasonal variability within and through the Indonesian archipelago to test the hypothesis that seasonal variability in mass transport within the archipelago is determined primarily by mutual adjustment between the seas in response to the seasonally varying pressure difference between the Pacific and Indian Ocean entrances. A key word in this hypothesis is *mutual*, which reflects my thinking that a proper understanding of seasonal variability cannot be achieved by studying individual straits within the archipelago and local wind-stress variations.

APPROACH

The approach is novel, and motivated by Wajsowicz's (1996) idea on understanding how to *parameterize* the effects of the complex, small-scale geometry of the archipelago in a GCM of the steady circulation by drawing an analogy with the analysis of complex electrical circuits: The archipelago is modeled as a collection of capacitors (seas), and resistors (frictional straits) and inductors (inertial effects), which modulate the discharge rate of the capacitors, subject to specified external AC/DC voltages (large-scale wind stress over the west Pacific and east Indian Oceans).

WORK COMPLETED

An analytical model based on the multiple island rule, Wajsowicz (1993), was coded up for computational visualizations, and used to investigate how the circulation within and through the Indonesian seas depended on the frictional properties of various straits within the archipelago. The mean, and annual and semi-annual harmonics, in depth-integrated transport were computed and compared with those obtained from the Parallel Ocean Climate Model (POCM) simulation of 1987-95 conducted by Prof. A.J. Semtner's group at NPGS, Monterey in lieu of real observations.

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These results, and the results obtained last year from analysis of POCM, were tidied up for publication. A substantial paper entitled *Models of the Indonesian Seas* was submitted to the *Journal of Physical Oceanography* in October 1997.

RESULTS

Calculations assuming all of the passages within the archipelago are wide and deep yield an archipelago circulation at odds with observations. A large westward transport through Luzon Strait passes southward through the South China Sea into the Sulu Sea and exits into the Pacific Ocean through the Celebes Sea. There is a northwestwards transport through the remainder of the archipelago. By successively closing straits under the assumption that frictional effects are sufficient to arrest flow in the strait, an understanding is built up of why the mean circulation in the archipelago is as observed and as simulated in POCM, see Fig. 1. For example, assuming Torres Strait is substantially blocked by friction yields a more recognisable archipelago transport system. The Celebes Sea and Makassar Strait is not the dominant pathway for the throughflow unless straits connecting the Philippines to the Asian continent are substantially blocked. However, the need to block off these straits to obtain the observed significant transport through Makassar Strait does not imply that the throughflow is driven by the pressure head associated with the North Pacific wind-stress curl, which drives the Kuroshio and Mindanao Currents. It is driven by the South Pacific wind-stress curl, and is affected by the latitudinal blocking extent of Australia. No significant transport occurs through Timor Strait unless straits to the west are substantially blocked.

Regarding the seasonal cycle, there is negligible transport below 500 m at annual period within POCM's archipelago, which suggested that the numerous islands and sills within the archipelago enhance the adjustment to the applied wind stress locally. Hence, island-rule-based models of the archipelago forced by local wind stresses are valid for describing the annual harmonic. Experiments showed that forcing over the archipelago and Australia gave good agreement in terms of magnitude with POCM, see Fig. 2. Better agreement in phase within the straits and seas is obtained by extending the models to include frictional effects outside western boundary layers, which enabled the influence of wind stress variations to be felt in directions other than just to the west, as in the original island rule. This was identified as particularly important for the Philippine-Palawan-Kalimantan group. It enabled the southward transport in Makassar Strait to be a maximum in boreal summer counter to the peak in prevailing winds.

The annual period signal is effectively a combination of a barotropic and first baroclinic mode, which have mutually adjusted to give no flow below 500 m. The semi-annual period signal has a second baroclinic mode component, which gives the previously noted capacitor effect. The archipelago has not adjusted at this period, and so analysis using a model based on Sverdrup dynamics cannot be justified.

Analysis of seasonal variations in the west Pacific of POCM showed that the gyres did not close sufficiently differently to change the water mass origin of the throughflow on seasonal timescales; it is fed from the SEC via a broad zonal jet or a western boundary current.

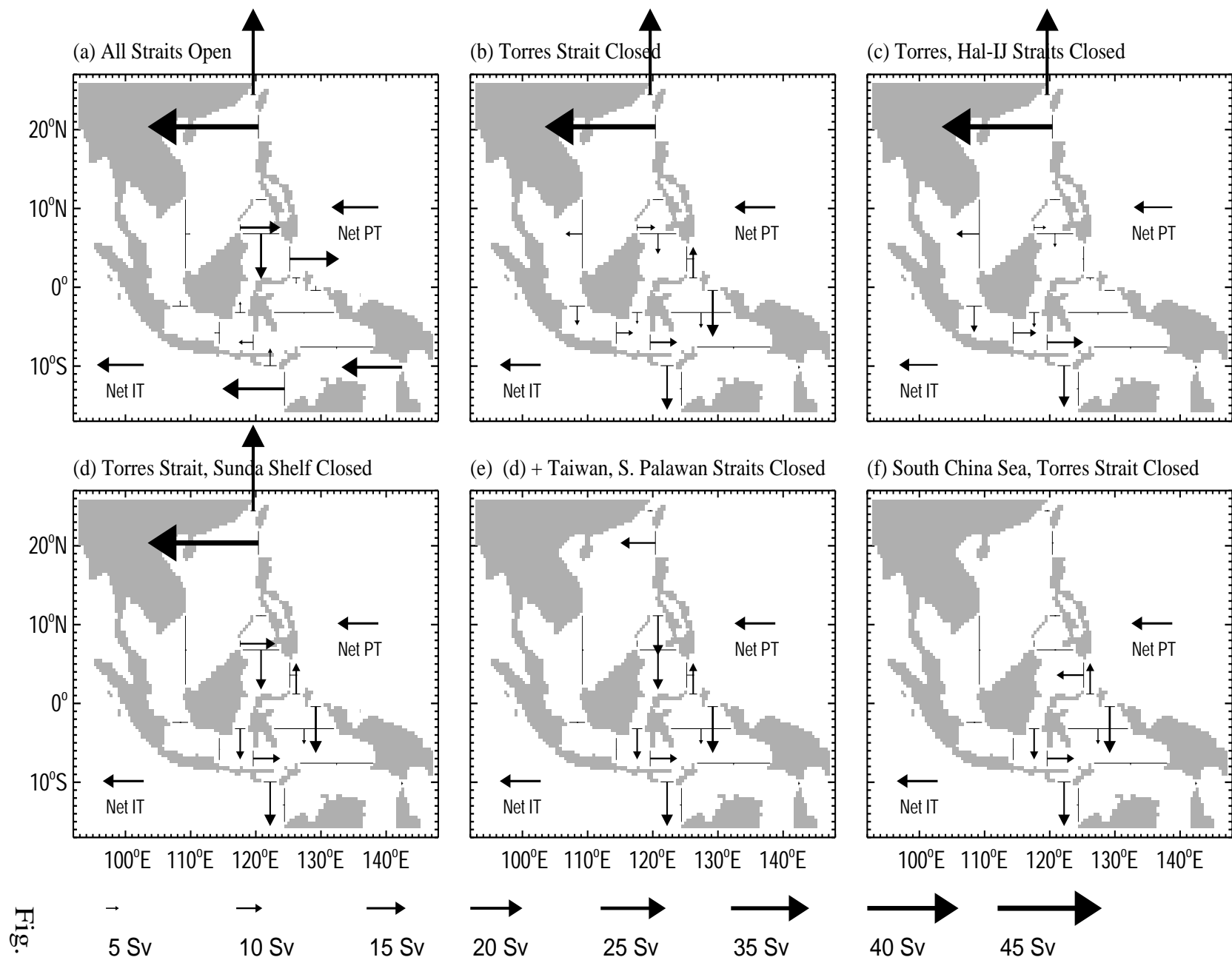


Fig. 1

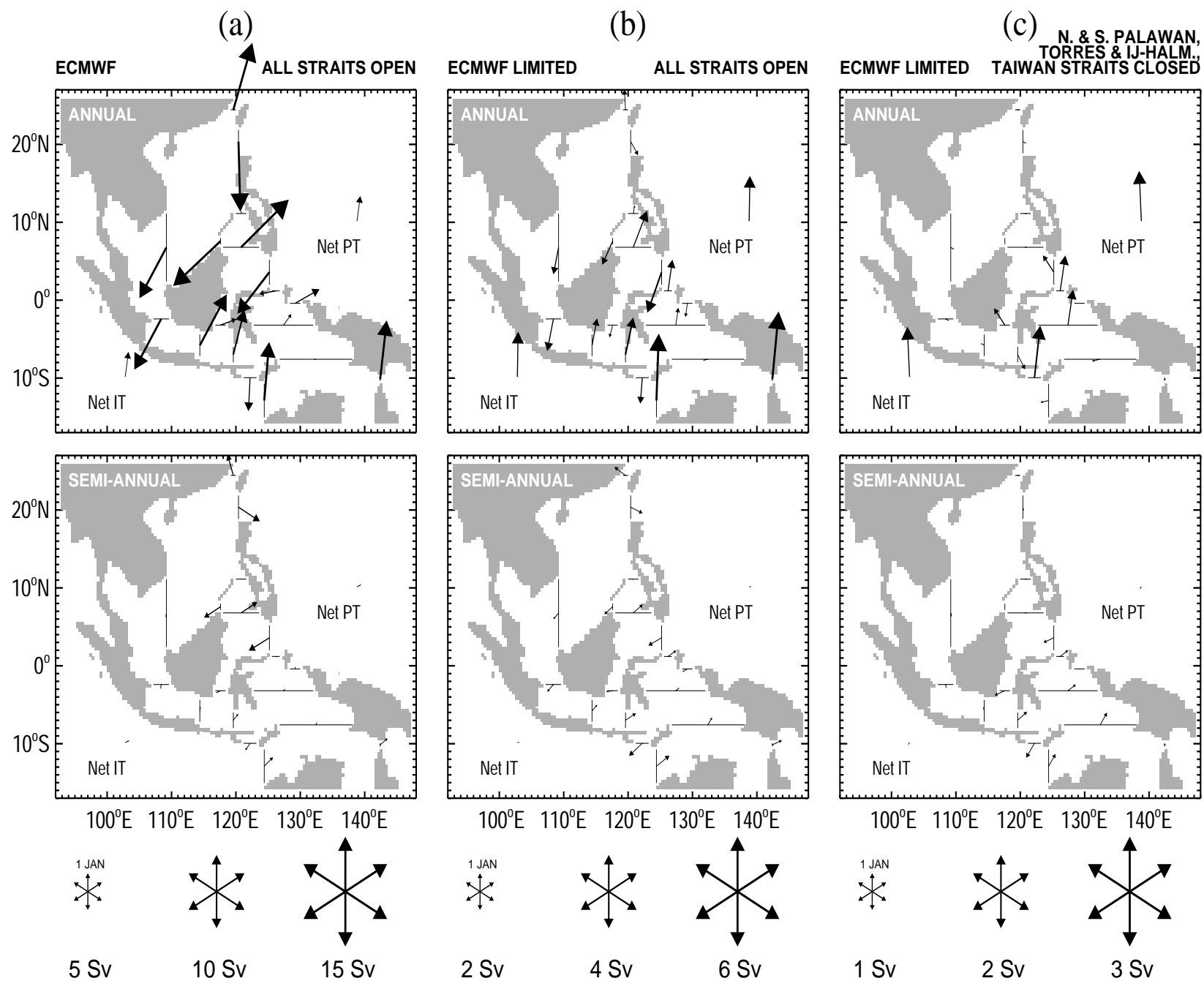


Fig. 2

IMPACT/APPLICATION

The development of sophisticated, numerical models for forecasting the ocean circulation and hydrographic state is a priority for ONR, as is knowledge and understanding of the ocean circulation in strategically important regions such as the Indonesian archipelago and other east Asian marginal seas.

TRANSITIONS

My results presented at the AGU West Pacific Conference, Brisbane, July 1996 relating to how to look at and interpret results from a GCM had a significant impact on the community and their subsequently published papers. I have sent copies of my manuscript *Models of the Indonesian Seas*, submitted to the *Journal of Physical Oceanography*, October 1997 to interested parties, and am discussing diagnostic applications of the model with newly-available data sets.

RELATED PROJECTS

I am also funded by NASA to investigate the effect of variations in the Pacific's heat and fresh-water fluxes on the Indian Ocean on seasonal-to-interannual timescales. These variations are felt directly through changes in the properties of the Indonesian throughflow. The results described above are important to this project, as the investigation involves running finite-difference numerical models of the Pacific and Indian Oceans, and the question about which straits and islands need to be included arises.

In general terms, the study provides a theoretical framework to support ONR's ongoing field program in the region (Gordon's ARLINDO and Bray), and the numerical primitive-equation modeling research at NRL, Mississippi (Hurlburt, Kindle & Preller) and NPGS (Semtner). As noted previously, important findings have been made of interest to the ENSO community and to observation and modeling comparison projects.

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